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Battery Powered Handheld Drain Cleaner

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Abstract

By pairing up with Ridge Tool Company in Elyria, Ohio, we developed a competitive redesign based on their K-45 Sink Machine. Some goals set forth at the beginning were to take the machine from a corded system with a brushed motor to a battery powered one with a brushless motor, and to address some consumer concerns in regards to weight support and ease-of-use. Our final objective was to assemble a functional prototype that could be submitted to Ridge Tool Company for review. This redesign should help this machine remain competitive in the field, and give us the chance to present our proposed redesign to upper management in the company.

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Introduction

We partnered with Ridge Tool Company from Elyria, Ohio, for our Senior Design Project/Honors Research Project. We were given the task of redesigning the company's K-45 Sink Machine to make it more competitive in the market. This product is used to unclog drains by extending an adjustable length of rotating cable into the drain. The cable has multiple end attachments to deal with various kinds of clogs and can handle tight twists and turns in plumbing. Once in contact with the clog, the cable spins so that the attachment can attack and remove the blockage. This machine contributes significantly to the company's financial success each year. With increasing competition in the market space, Ridge is looking to improve their product to ensure its continued success. The improvements they are looking to make are based on a variety of factors, but are focused most prominently on customer feedback.

We designed improvements to many parts of this product. The current model (Figure 1) is corded, and Ridge highly emphasized their desire to change to a battery powered system. The majority of the competition offer battery powered options that are comparable to the K-45. It is, therefore, essential to make this change. Ridge also tasked us with changing out the current brushed motor with a brushless motor. A complete redesign of the handle is required to accommodate these changes. Since we had to redesign the handle, we explored a variety of ergonomic factors in order to improve its overall comfort in the process.

Beyond the aforementioned focuses, we also looked to remedy customer complaints and maintain a competitive price point. The largest complaint we explored solutions for is the spinning drum which twists the cable in the drain. Users tend to rest the tool against their body to support the heavy machine, bringing the spinning drum uncomfortably close. Customers would

like to see this piece in some form of housing to make the tool more comfortable to use. A great deal of our work has gone into creating an enclosure for the drum. We conducted research into a pre-existing patent held by the Milwaukee brand for a similar feature to ensure our solution was not an infringement. A weight support solution was also explored to allow the tool to rest farther away from the user's body.

Upon completion of this project, we will be handing over a fully functional prototype, along with all of our research and future suggestions, to the Ridge team so that they may continue the redesign process. Our team is hopeful that we will see a final product on the market in the future with many of the changes we have made.

Background

Figure 1: Current K-45 Sink Machine Design

The K-45 Sink Machine has been through several design iterations throughout its lifetime. For example, in the current model the power cord feeds out the bottom of the handle, but in the previous generations the machines featured a power cord that fed out the side,

providing a flat base to rest on (see Figure 2). Each design iteration of the drain cleaner tool has been in response to changes in the market and/or technology; our design follows this pattern and is our response to the current consumer market. By converting to battery-power, the flat base feature will once again be present, which we hope future consumers will appreciate.

Figure 2: Example of a RIDGID tool with a power cord that feeds out the side

Customer Reviews

One of the first steps in our design process was to research customer reviews for the K-45 tool, as well as reviews for competitive products in the market. We wanted to use customer feedback to improve aspects of the K-45 that were frequently mentioned. As part of our research, we also interviewed a frequent user of the K-45 machine (see Dale's interview in Appendix) to pick up on nuances not mentioned in online reviews. We also looked at reviews for competitor's products so that we could build off of their positive aspects, while avoiding their negative ones.

a. K-45 Reviews

The K-45 was frequently praised as a high-quality, reliable tool. Many people also appreciated the AutoFeed and its speed, the replaceable cable, the end attachments, and the lifetime warranty. On the other hand, there were many complaints about the weight of the tool and its awkwardness to hold. Because of the spinning drum, the tool cannot be comfortably held against the body, and because of the cord that extends from the bottom of the handle, the tool cannot be rested on one's knee or a surface. Additional complaints include that the user has no way of knowing how much cable remains in the drum, that the end of the cable is not attached to the drum, and that the tool is generally more expensive than other Home Depot brands. We will be working to improve many of these pain points, while still maintaining RIDGID's reputation for quality.

b. Competitive Products Reviews

To continue our research, we found four products on the market that were most similar to, and provided the most competition to, the K-45. The biggest advantage to the first tool, made by Ryobi, was its drastic difference in cost. The Ryobi tool sales price is around $70 according to multiple retailers versus the K-45, which sales price is over $300 from the same retailers. In addition to the affordability, customers appreciated the click-on battery style, the autofeed, the portability, and the weight distribution. However, the effects of the lower cost can be seen in the tool's criticisms. The tool is considered low quality and unreliable, as it often breaks and is not easily repairable. Additionally, the cable kinks easily and does not maneuver pipe corners well, often getting stuck, and can only be used in smaller pipes with smaller clogs. Various other

complaints were that the battery is not included in purchase, that the drum is not replaceable, that the spinning drum is exposed, and that the cable feed rate is slow.

The next product we looked at was made by Milwaukee, which can be found at a similar price to the K-45. Two features that were highly reviewed for this tool that the K-45 lacks are the covered drum and the cordless design. Milwaukee's design makes cleaning of the cable and drum easier and they offer a convenient storage container that prevents rust by positioning the nose down to allow drainage. Customers also wrote about the good battery life and the ability to rest the tool on the floor. Conversely, customers complained that the cable crimped after the first use, that the cable tangled inside the drum, and that the tool did not have an autofeed feature.

The final two tools we looked at were made by DeWalt and General. Customers appreciated cordless tools and strong battery life because of the ability to maneuver in hard-to-reach places. Reviews also mentioned easy tool repairability and after-market purchases to help manage the weight. On the other hand, customers complained when the tools did not come with a battery or charger, or if the tool only worked with a specific type of battery. Additionally, customers gave negative reviews when replacement parts were either hard to find or expensive. Lastly, the spinning drum was negatively mentioned in reviews whenever it was not covered in the design.

Objective Tree

After researching customer concerns, we selected areas that we aimed to improve. We created the objective tree (see Appendix, Figure A3) based on the values of two groups: Ridge Tool Company and their consumers. The consumers' values were given the most weight as they

control the market (and through the market, this project) and determine the success or failure of the redesign. The other objectives in the tree were given to us by Ridge Tool company as goals of the project.

Decision Matrices

Choices of materials/design for different components were based on our research into viable options as indicated in the decision matrices of Figures 3 to 8.

Drum Enclosure			Designs:	0-10	
Engineering Requirements	Subcategories	Weighted Score	Transparent P.C.	Opaque P.C.	Cage
Quality		0.35			
	Durability	0.14	7	7	9
	Ease of Use	0.105	0	0	0
	Reliability	0.105	9	9	7
Cost		0.15			
	Sourcing of Material	0.015	9	9	7
	Repairability	0.0525	9	9	7
	Price	0.0525	9	9	7
	Manufacturability	0.03			
	Time to Produce	0.015	8	9	5
	Ability to Produce	0.015	8	9	6
Safety		0.4			
	Consumer Safety	0.32	8.5	8	5
	Damage Free Use	0.08	8	8	7
Additional Features		0.1			
	Weight Support/Reduction	0.035	8	8	5
	Battery Life	0.015	0	0	0
	Drum protection	0.035	8	8	7
	Cable Length Tracking	0.01	8	0	0
	Ergonomic Design	0.005	0	0	0
		Totals:	7.245	7.035	5.58

Figure 3: Decision Matrix for the Drum Enclosure Material

We initially wanted to pursue a transparent plastic cover for the drum cover. After further investigation into possible materials, we found that we would need a very durable material to pass required drop testing. Clear plastic options that are within the price range of this product are not strong enough to survive the testing based on previous experience. We were also concerned

that minor surface scratches would obstruct the view, therefore, we have decided to use an opaque plastic.

Drum Fixture			Designs:	0-10	
Engineering Requirements	Subcategories	Weighted Score	Drum & Plate	Walnut	Plate & Two Half
Quality		0.35			
	Durability	0.14	8	5	7
	Ease of Use	0.105	8	6	4
	Reliability	0.105	0	0	0
Cost		0.15			
	Sourcing of Material	0.015	0	0	0
	Repairability	0.0525	3	9	3
	Price	0.0525	0	0	0
	Manufacturability	0.03			
	Time to Produce	0.015	8	7	7
	Ability to Produce	0.015	0	0	0
Safety		0.4			
	Consumer Safety	0.32	0	0	0
	Damage Free Use	0.08	0	0	0
Additional Features		0.1			
	Weight Support/Reduction	0.035	0	0	0
	Battery Life	0.015	0	0	0
	Drum protection	0.035	0	0	0
	Cable Length Tracking	0.01	0	0	0
	Ergonomic Design	0.005	0	0	0
		Totals:	2.2375	1.9075	1.6625

Figure 4: Decision Matrix for the Drum Fixture Shape

After deciding on the material of the drum fixture, we had to determine the shape of the drum. Each of us developed an idea that was put to the test through the decision matrix (Figure 4).

Ergonomic Design			Designs:	0-10		
Engineering Requirements	Subcategories	Weighted Score	Texturing	Finger Grooves	Trigger Guard	Extended Base Trigg
Quality		0.35				
	Durability	0.14	9	9	7	9
	Ease of Use	0.105	0	0	0	0
	Reliability	0.105	0	0	0	0
Cost		0.15				
	Sourcing of Material	0.015	7	9	9	9
	Repairability	0.0525	0	0	0	0
	Price	0.0525	0	0	0	0
	Manufacturability	0.03				
	Time to Produce	0.015	7	9	9	9
	Ability to Produce	0.015	0	0	0	0
Safety		0.4				
	Consumer Safety	0.32	5	6	9	8
	Damage Free Use	0.08	0	0	0	0
Additional Features		0.1				
	Weight Support/Reduction	0.035	0	0	0	0
	Battery Life	0.015	0	0	0	0
	Drum protection	0.035	0	0	0	0
	Cable Length Tracking	0.01	0	0	0	0
	Ergonomic Design	0.005	5	6	9	8
		Totals:	3.095	3.48	4.175	4.13

Figure 5: Decision Matrix for Ergonomic Design Factors

In this case (Figure 5), a physical trigger guard option had the highest point score. However, we were concerned about the safety of a user wearing gloves. We made the decision to instead pursue the extended base trigger which would still increase the overall safety without facing any interference from work gloves.

Cable Counter			Designs:	0-10	
Engineering Requirements	Subcategories	Weighted Score	Viewing Window	Electric Counter	Colored Cable
Quality		0.35			
	Durability	0.14	9	6	5
	Ease of Use	0.105	6	9	6
	Reliability	0.105	5	6	5
Cost		0.15			
	Sourcing of Material	0.015	6	4	8
	Repairability	0.0525	7	4	9
	Price	0.0525	0	0	0
	Manufacturability	0.03			
	Time to Produce	0.015	9	4	8
	Ability to Produce	0.015	7	4	9
Safety		0.4			
	Consumer Safety	0.32	0	0	0
	Damage Free Use	0.08	0	0	0
Additional Features		0.1			
	Weight Support/Reduction	0.035	0	0	0
	Battery Life	0.015	10	9	10
	Drum protection	0.035	0	0	0
	Cable Length Tracking	0.01	6	9	3
	Ergonomic Design	0.005	0	0	0
		Totals:	3.3225	3.03	2.8825

Figure 6: Decision Matrix for a Cable Counting Method

This area (Figure 6) was one of the lowest on our list of concerns, and it was only to be completed if time allowed. Because we decided not to pursue a transparent plastic cover for the drum, a viewing window to track the cable length would not be possible. We also decided not to pursue the electric cable counter due to the cost and complexity. And even our final option to color the last section of the cable was not preferred due to the likelihood that it would wear off.

Weight Support			Designs:	0-10		
Engineering Requirements	Subcategories	Weighted Score	Bipod	Tripod	Strap	Full-structure
Quality		0.35				
	Durability	0.14	6	7	4	9
	Ease of Use	0.105	7	8	7	4
	Reliability	0.105	9	9	9	9
Cost		0.15				
	Sourcing of Material	0.015	8	7	9	5
	Repairability	0.0525	8	8	9	5
	Price	0.0525	8	8	9	5
	Manufacturability	0.03				
	Time to Produce	0.015	7	7	9	4
	Ability to Produce	0.015	8	8	8	6
Safety		0.4				
	Consumer Safety	0.32	7	8	6	9
	Damage Free Use	0.08	8	8	9	6
Additional Features		0.1				
	Weight Support/Reduction	0.035	7	8	6	10
	Battery Life	0.015	0	0	0	0
	Drum protection	0.035	9	9	6	10
	Cable Length Tracking	0.01	0	0	0	0
	Ergonomic Design	0.005	0	0	0	0
		Totals:	7.145	7.73	6.635	7.435

Figure 7: Decision Matrix for Weight Support Options

In our original assessment (Figure 7), the tripod design option received the highest rating. However, after further discussion with the Ridge team, we decided to instead pursue the bipod design to enable users to take advantage of a push-pull motion.

Market Requirements Event (MRE)

Engineering Requirements	Subcategories	Weighted Score	Must-Have	Should-Have	Could-Have	Technical Risk (H, M, L)	Schedule Risk (H, M, L)	Cost Risk (H, M, L)
Quality		0.35						
	Durability	0.14	X			L	L	L
	Ease of Use	0.105	X			L	L	L
	Reliability	0.105	X			L	L	L
Cost		0.15						
	Sourcing of Material	0.015						
	Repairability	0.0525		X		L	L	M
	Price	0.0525	<$450	<$400	<$350	L	L	M
	Manufacturability	0.03						
	Time to Produce	0.015	15min	13 1/2 min		L	L	L
	Ability to Produce	0.015		In-house		L	L	L
Safety		0.4						
	Consumer Safety	0.32	X			L	M	L
	Damage Free Use	0.08	X			L	L	L
Additional Features		0.1						
	Weight Support/Reduction	0.035		Bipod/Strap		L	L	M
	Battery Life	0.015	>5hr	>10hr	>24hr	M	L	H
	Drum protection	0.035	Enclosure			L	M	M
	Cable Length Tracking	0.01		Clear drum face	Counter	L	M	M
	Ergonomic Design	0.005		Finger notches in grip		L	L	L

Figure 8: Market Requirements Event

The MRE was created according to Ridge team specifications. It contains some information that is considered "ideal" and may not be obtainable or at least not obtainable by our team in the time limit of our school year. We have attempted to cover each category to the best of our ability and have already discussed with the Ridge team which areas they plan to pursue at the completion of our project.

Patent Research

One critical factor to consider during any design process is the existence of patents for similar products. We were led by our project supervisor at Ridge Tool to two patents that might affect changes we would be making to the K-45. The first is Patent #9884353 by Milwaukee. This patent covers every aspect of their drain cleaner, but we were only concerned with their description of the "shroud" to cover the spinning drum, shown in Figure A1 of the Appendix. Since this is a feature that we were looking to add to the K-45, we needed to examine their wording in the patent so that we would not infringe on their design. In their patent they say, "The drain cleaner also includes a shroud fixed to and extending forwardly from the handle assembly". In focusing on the word "fixed", Milwaukee seems to be claiming that the drum cover is permanently attached to the tool and cannot be removed, therefore we needed to design our drum enclosure to be removable.

The second patent is Patent #9234342, which describes a handheld drain cleaner with "an extendable monopod support secured to the motor housing", shown in Figure A2 of the Appendix. Since weight support is an important feature on our objective tree, we also needed to keep this patent in mind to ensure that our design would differ. The monopod described in this

patent is permanently attached to the motor housing of the tool and is located directly beneath the center of gravity. The monopod support is the only leg that the tool can be rested on, so it must be supported by the user at all times. Comparatively, the bipod we designed to support the tool's weight (see Figure 12) is detachable, located in front of the center of gravity, and free-standing, because the tool can be rested on the two legs of the bipod and the downward facing handle to form a tripod.

As we continued to work on our bipod support, we looked into five of the patents referenced in the monopod patent to ensure that our design differed. The five patents were Patent #1807549, Patent #2278067, Patent #2318172, Patent #2940099, Patent #2188393. One of the main differences in these inventions versus ours was the fact that the drain cleaning machine could not be detached from the support and used as a handheld device. Additionally, many of these inventions did not allow for forward and backward shifting of the tool during use and could not be adjusted in height.

Ergonomic Considerations

In our redesign process, we will be making multiple changes that will require us to redesign the molds for the handle and other main portions of the K-45 tool. Since we will be redoing the molds, we took the opportunity to look into the ergonomics of holding the tool and consider other possible handle orientations. The first resource we found online was a brochure published by OSHA, the Occupational Safety and Health Administration, titled "Ergonomics: The Study of Work". The brochure stressed the importance of keeping the body in a natural, resting position while working to minimize stress and reduce the risk of injury. For our tool, we

are mainly concerned with the positions of the wrists and elbows. To minimize stress, elbows should remain bent at a 90 degree angle, and wrists should remain straight. Also, any frequent bending or twisting motions of the wrists should be avoided. The current design of the K-45 with a drill-like handle meets both of these requirements well.

Another consideration is to design the handle so that as much of the inner hand and fingers are in contact with the handle as possible. From the article, "Design-In Ergonomics Guidelines", it is suggested that "tools should be designed with an oval shaped handle of 1.25 inches by 1.0 inches", and should ideally be longer than 5 inches. In addition to the handle shape, it is important to consider weight distribution. Preferably, the handle should be located near the center of gravity, keeping the weight distribution as close to the wrist as possible. When we evaluated other handle orientations, such as the inline-design, they did not meet this requirement as well as the current drill-design.

Design Decisions

a. Handle Shape

Due to the need to redesign the handle to accommodate the new brushless motor as well as the change from corded to battery powered, we decided to explore options that may possibly improve the overall ergonomics. The K-45 has a traditional drill handle. We compared all options to that style. Options included both drill style and inline style setups with a wide variety of handle orientations. One of the most important factors to our decision was comfort. The average K-45 user has to contend with locations from floor level, with the possibility of cabinetry interference, to above the head, which often involves a ladder. The tool must be as

comfortable as possible in all positions between these points. After a great deal of comparison that included speaking with an actual user, we concluded that the best choice for our redesign was to maintain the traditional drill style while making minor improvements for hand placement.

b. Battery Selection

The current K-45 design is corded and Ridge emphasized their desire to change the design to a battery-powered system. In order to take the first steps to this conversion, our group needed to conduct an analysis of collected data to determine its feasibility. Our company supervisor instructed us to complete "simplified" calculations to provide base numbers for the system. We were provided with testing data previously acquired by Ridge team members in order to calculate a worst case scenario.

Equations:

$P = VI$, where Power is in Watts, Voltage is in Volts, and Current is in Amps

$C = xT$, where Capacity is in Amp-hours, Current-draw is in Amps, and Time is in hours

$P_{DC} = P_{AC} / 1.5$, where Power is in Watts

(See Table A1 in the Appendix for calculations)

First we extracted the power from the data. This power is AC and to apply it to a battery-powered system we have to convert to DC power. Using the new DC power and the given voltage of 18V, we calculated a new current. From the new current and available battery sizes, we were able to calculate the maximum amount of time it will last while in use. For our "simplified" calculations we chose to disregard factors such as cycle life and rate of discharge.

While assessing consumer reviews, we found users reported that during the average job they spent between 10-15 minutes engaging the blockage with the drain cleaning tool. We found that while the originally proposed 2.5 Ah battery would work, it would only last 0.18 hours or 10.8 minutes. We have provided the recommendation for a 4 Ah or more battery to be included with the tool when sold as it would last 0.29 hours or 17.4 minutes. This recommendation would increase the overall price of the tool, but we strongly feel that it would be positively received by the customer base. Further and more detailed calculations will be conducted by the Ridge team when the project is closer to the consumer-ready design.

c. Drum Enclosure

Figure 9: Drum Enclosure Model

One of the major customer complaints of the current K-45 model is the exposed rotating drum. To address the issue, we decided to enclose the drum. It was important for us to keep the Milwaukee patent in mind while determining viable options (see Patent Research section). We

wanted to minimize new and additional parts and work with as many pre-existing parts for both cost and ease of production/manufacturing. It was highly important that we maintain the ease of use of the sink machine. We did not want to create a new model that was difficult and/or time consuming to clean and reload because customer reviews favored that convenience. With these concepts in mind, we decided on the "drum and plate" design (see Figure 4). This design includes expanding the front and back plates to enclose the drum (see Figure 9). Both parts will not spin and will therefore solve the issue. With this change, we also revised the design for the drum turner.

d. Drum Turner

The drum turner is a plastic component that fits around the outside of the replaceable drum. The drum containing the cable is slid into the drum turner using four matching grooves. The grooves keep the two components spinning together at all times, while also allowing the replaceable drum to be taken out. This enables the consumer to easily remove the drum and cable to replace it or switch it out.

We utilized Ridge's existing design for the drum turner as much as possible in our design. However, we removed material on the side walls that we felt was unnecessary due to the addition of the drum enclosure. When we had our first version of the drum turner (Figure 10) 3D printed, we noticed that the walls seemed a little flimsy and we were not confident that the part would hold up while supporting a heavy, spinning drum. In addition, the drum turner could not reliably be connected to the turning mechanism in its current state. To fix these issues, we redesigned the drum turner by raising the side walls to provide additional support and extended

the middle shaft down in order to meet the turning shaft of the gearbox (Figure 11). The drum turner is now much more stable.

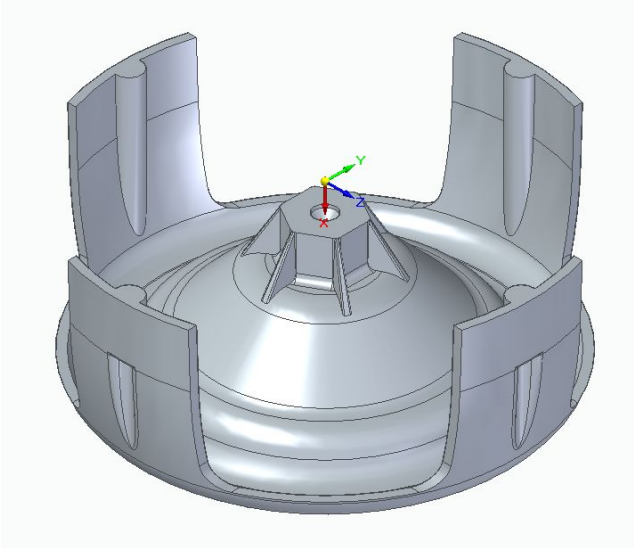

Figure 10: Drum Turner Model

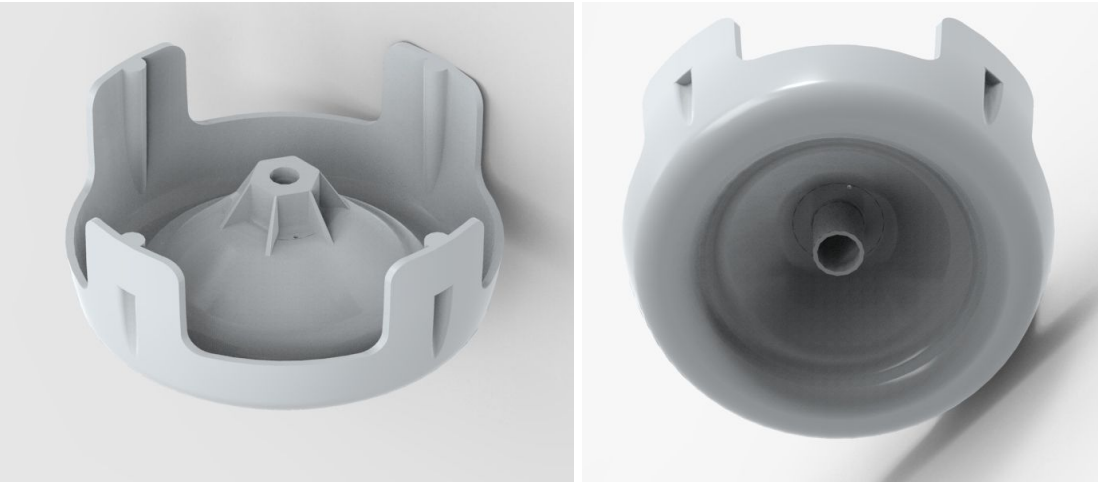

Figure 11: Drum Turner Model, redesign

e. Bipod Weight Support

After reading many customer reviews of the K-45 and similar machines, and also using the tool ourselves, we determined that one of the biggest issues is the heavy-weight and awkward weight distribution of the tool. We brainstormed several potential solutions to better support the weight of the tool, including a bipod, a tripod, a strap to wrap around the user's body, and a full frame that would hold the tool while resting on the ground (see Figure 7). First, we narrowed our options to either the bipod or tripod for their stability, reliability, and ease of use. However, we decided to pursue the bipod (Figure 12) as our final choice because two legs, rather than three, allow the tool to be pushed toward and pulled away from the drain during use, which is a common motion used to help remove clogs.

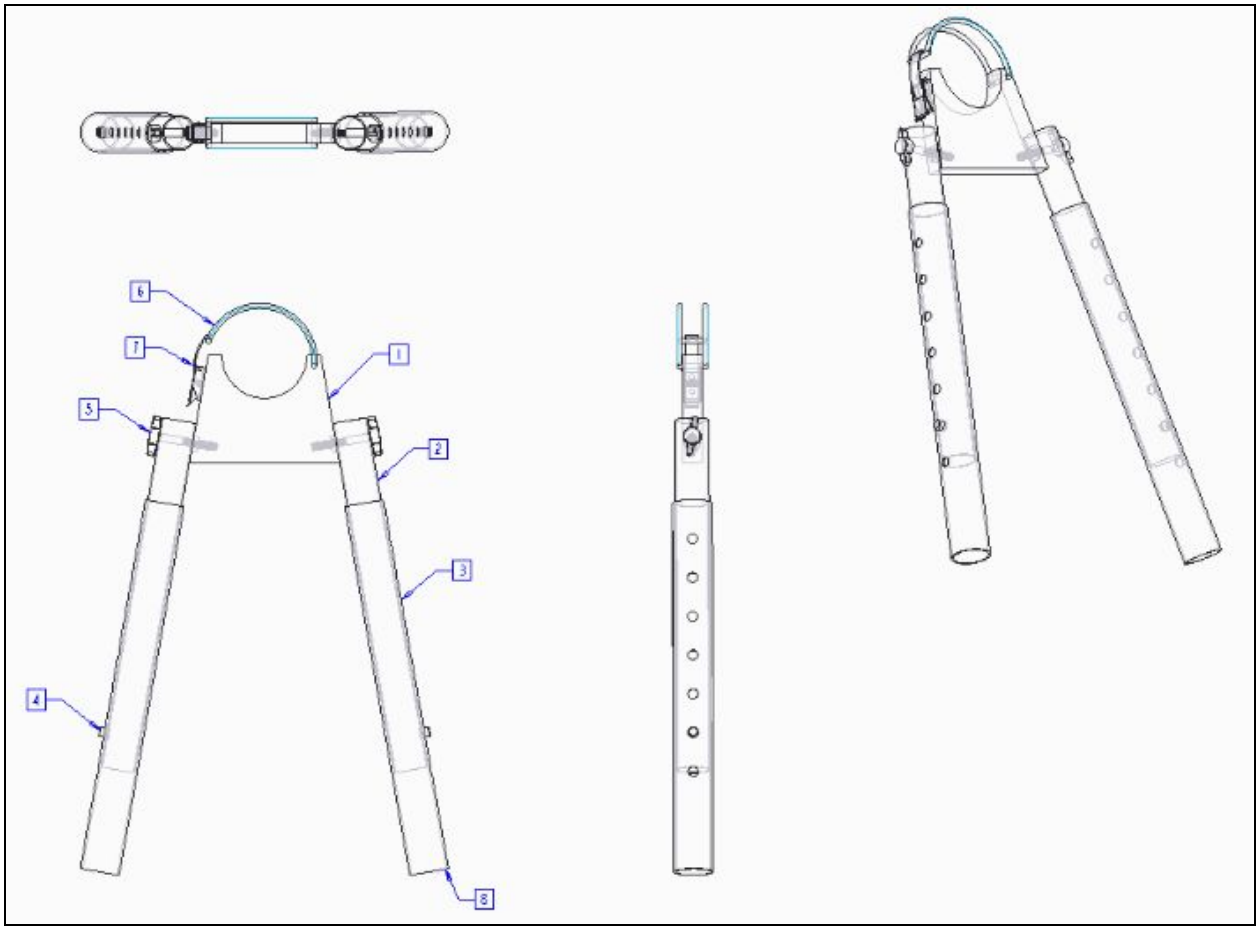

Figure 12: Bipod Weight Support Drawing

The base of our bipod [1] is shaped to be retrofittable to the nose of the K-45 machine. Attached to the base is a wire hook [6] that rotates open to allow the bipod to be easily attached or removed from the tool. A draw latch [7] holds the hook in place tightly wrapped around the nose of the K-45. The legs of the bipod are screwed [5] into the base and can be rotated and tightened at any angle. This is an important feature, because drain cleaners are used in many different situations, with different drain locations and heights. It was important for our bipod to be versatile for each consumer. The legs are made with two telescoping pieces, locked in place

by a push button [4], so the tool can be used at various heights. On the end of each leg is a rubber bumper [8] to provide friction so that the bipod does not slip during use.

When we presented our idea for the bipod support to Ridge, they were excited about the potential. We were able to meet with their patent attorney to discuss our idea, and we have been working on the paperwork to pursue a provisional patent application, with possible full patent application to follow.

Prototype

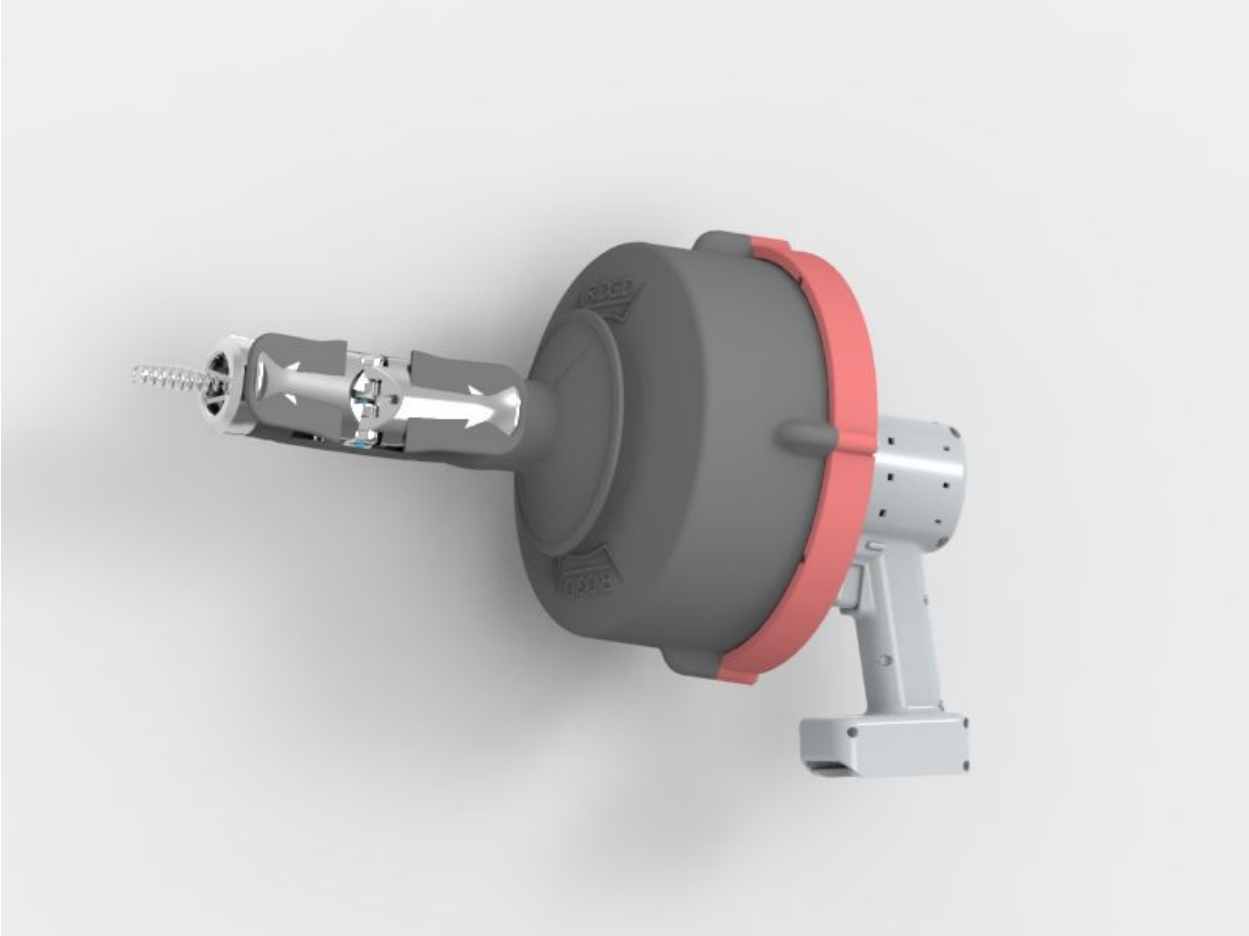

Figure 13: Full Prototype Model

Figure 14: Drum Enclosure and Turner Prototype Model

Figure 15: Fully Assembled Prototype

References

Banholzer, Hans T, et al. *Drain Cleaner*. 6 Feb. 2018.

Beesley, Daniel Joseph, and Jordan Roy Beesley. *Handheld Powered Cable-Drum Drain Cleaning Machine*. 12 Jan. 2016.

"Design_In Ergonomics Guidelines." Enterprise Operating System, 30 June 2017.

Emery, William M. *Sewer Cleaner*. 31 Mar. 1942.

Irwin, Lawrence F. *Improved Pipe Cleaning Machine*. 30 Sept. 1987.

Kollmann, Karl J. *Sewer Cleaner*. 14 June 1960.

K-45 Sink Machine. *Ridge Tool Company*, 19 Dec. 2018, https://www.ridgid.com/us/en/k45af-sink-machine

Long, Hugh. *Universal Tool*. 4 May 1943.

Reber, Amel. *Revolving Waste Pipe Opening Machine*. 26 May 1931.

Review of DEWALT 20-Volt MAX Cordless Brushless Drain Snake with Bonus 20-Volt 5.0Ah Battery Pack and Charger-DCD200BW205CK. *The Home Depot*, 12 Feb. 2019, https://www.homedepot.com/p/DEWALT-20-Volt-MAX-Cordless-Brushless-Drain-Snake-wit-Bonus-20-Volt-5-0Ah-Battery-Pack-and-Charger-DCD200BW205CK/307293119

Review of General Wire Power-Vee Drain Cleaning Machine includes 2 Cables, Cutter Set & Case,PV-A-WC. *Amazon*, https://www.amazon.com/General-Wire-Power-Vee-Cleaning-Machine/dp/B002PG31X0

Review of Milwaukee M18 FUEL 18-Volt Lithium-Ion Cordless Drain Cleaning Snake Auger with 5/16 in. Cable Drive (Tool-Only)-2772A-20. *The Home Depot*, 27 April 2018, https://www.homedepot.com/p/Milwaukee-M18-FUEL-18-Volt-Lithium-Ion-Cordless-Drain

Cleaning-Snake-Auger-with-5-16-in-Cable-Drive-Tool-Only-2772A-20/303229013

Review of RIDGID 115-Volt K-45AF AUTOFEED Drain Cleaning Machine with C-1 5/16 in. Inner Core Cable-35473. *The Home Depot*, 7 Feb. 2019, https://www.homedepot.com/p/RIDGID-115-Volt-K-45AF-AUTOFEED-Drain-Cleaning-Machine-with-C-1-5-16-in-Inner-Core-Cable-35473/202056529

Review of RYOBI 18-Volt ONE+ Drain Auger (Tool Only)-P4001. *The Home Depot*, 18 May 2018, https://www.homedepot.com/p/RYOBI-18-Volt-ONE-Drain-Auger-Tool-Only-P4001/206405601

Ridgid Pressing Tool RP-330 Manual. *Ridge Tool Company*, N.A., https://cdn2.ridgid.com/resources/media?countrycode=US&key=7cca1392-3381-45ec-9962-7a2a994079ef&languagecode=en&type=document

U.S. Department of Labor. *Ergonomics: The Study of Work*, Occupational Safety and Health Administration, 2000.

Wang, Ching-yi, and Deng-chuang Cai. "Hand Tool Handle Design Based on Hand Measurements." MATEC Web of Conferences, 2016.

Appendix

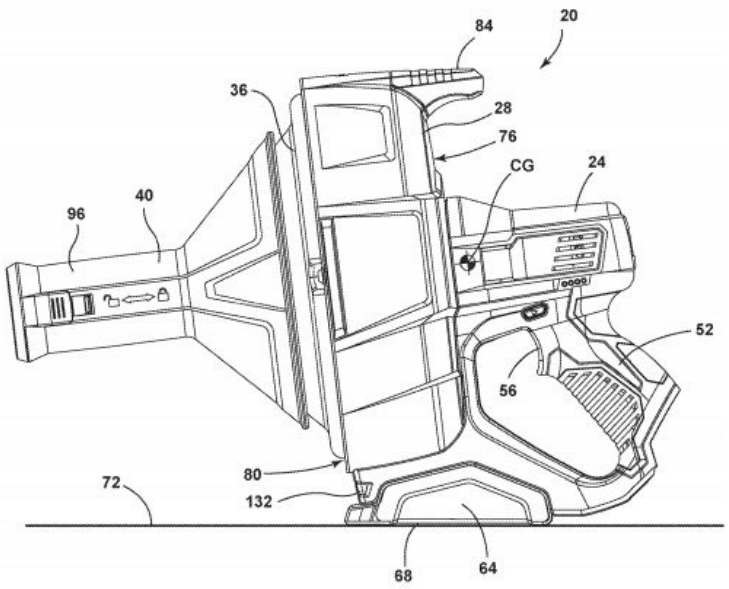

Figure A1: A sketch from Patent #9884353 showing the "fixed" shroud

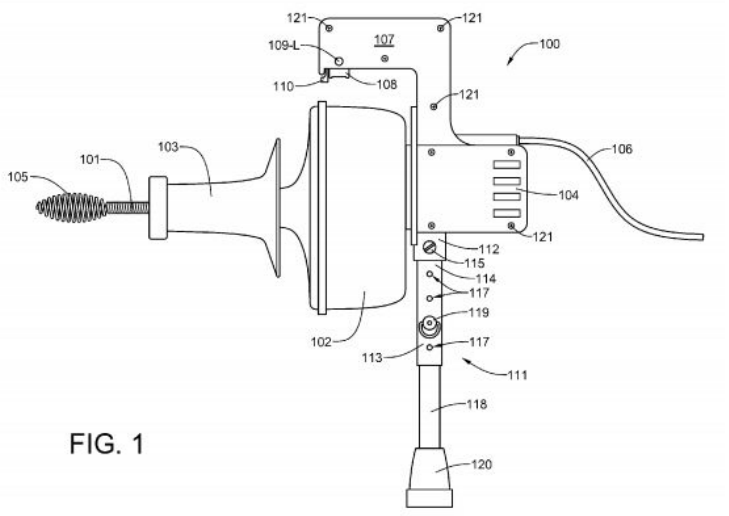

Figure A2: A sketch from Patent #9234342 showing the extendable monopod support

Current Data			New Data	
Voltage [V]	115.00		Voltage	18.00
Current (rated) [A]	3.20		Current	13.63
Power [W] = V*A	368.00		Power [W] = P/1.5	245.33
2.5Ah Battery [Hr]	0.78		2.5Ah Battery [Hr]	0.18
4Ah Battery [Hr]	1.25		4Ah Battery [Hr]	0.29
6Ah Battery [Hr]	1.88		6Ah Battery [Hr]	0.44
9Ah Battery [Hr]	2.81		9Ah Battery [Hr]	0.66

Table A1: Battery Selection Calculations

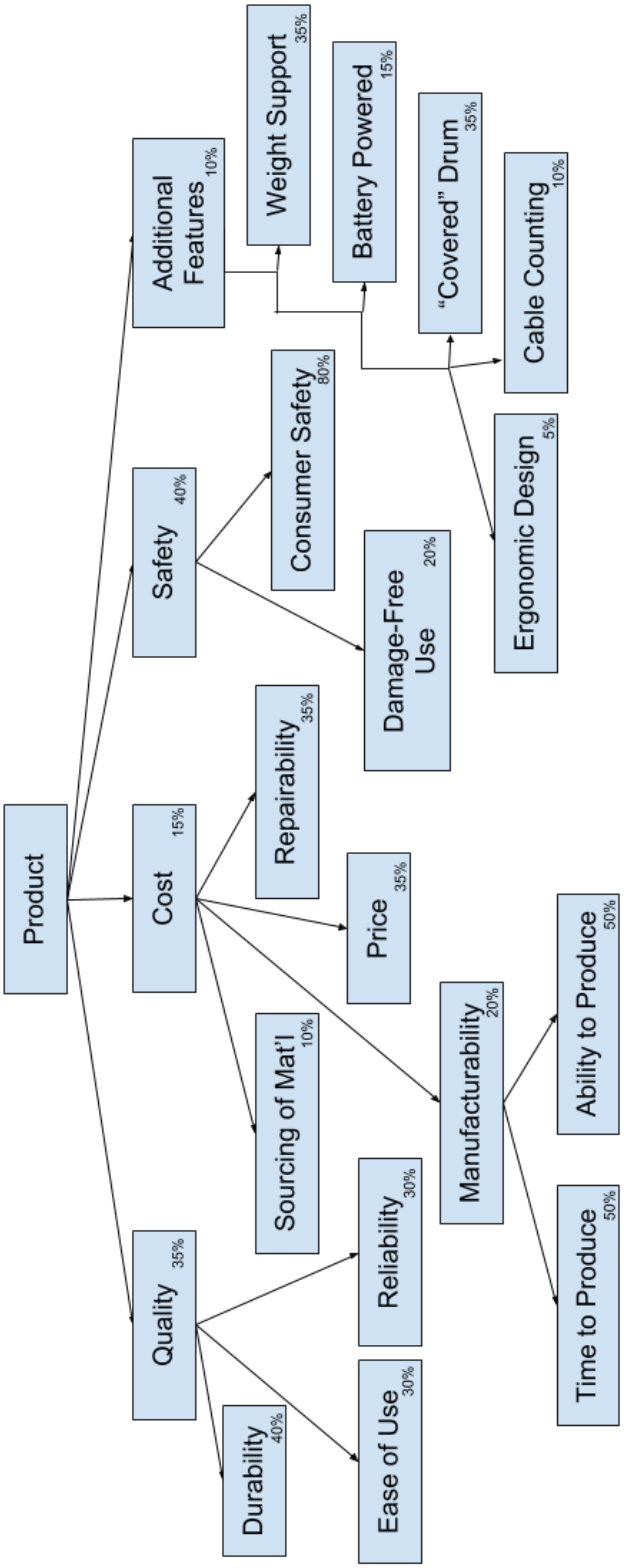

Figure A3: Objective Tree

Dale's Interview

Background

- Used in a government facility for several years as well as some home-use
- Non-autofeed model

I asked 3 questions and tried not to steer the conversation to anything in particular. I was only after his own thoughts on the K-45.

Generalized review

- "Nice tool"
- Good quality/well made
- Found the interchangeable augers extremely useful
- Had high praise for the drill handle for its "comfortable hold" and ability to handle "lots of angles"

Pain Points/Complaints

- Heavy
- He struggled not knowing the extended cable length
    - Would often pull the cable out of a pipe fully extended and use a tape measure to find the length
- When dealing with a blockage he found that the tool would "just keep torquing" and "the cable would just keep twisting" which caused kinks ruining the cable

Suggestions for Improvement

- Cable length tracker
- BATTERY
    - Told me a story about having 4+ extension cords connected end to end to reach a blocked pipe in the "worst damn place possible"